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Green space in an extremely exposed part of the city center "Aorta of Warsaw" - Case study of the urban lawn

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Abstract

The method of developing city centers is the responsibility of local authorities, which must reconcile the interests of investors applying for valuable land with the utility needs and expectations of residents regarding, inter alia, free squares and green enclaves. This study was conducted in Warsaw (Poland). In the study area, for 20 years there has been a discussion about how the area should be developed. So far, the area is used as lawns. During the monitoring period, 72 plant taxa were found. It is possible to state that an urban lawn is an ecosystem with relatively stable conditions, which is, however influenced by human disturbance and specific stress in the city. A city lawn is an oasis of greenery that is easy to set up and maintain, in the case of modernization, it does not generate large costs related to its restoration, unlike gardens. Maintaining an intensive lawn requires not only the selection of appropriate grass species resistant to the influences of the urban environment, but also the optimal way to us it. This research can be used to choose the optimal method for managing and maintaining greenery, considering the conditions of spatial development and environmental factors.

Keywords Warsaw · City development · Urban ecosystems · Urban greenery · Lawns · Vegetation heterogeneity

Introduction

Contemporary cities are characterized by growing density, while gradual overpopulation causes other problems in finding adequate apartments and exurbanisation (Cortinovis et al. 2019; Des Roches et al. 2021; Xi et al. 2022). The number of people inhabiting urban areas is estimated to increase by up to 70% by 2050 (Unhabitat 2009; Baldock 2020; Song et al. 2021). This fact affects city dwellers, exposing them to negative factors such as low air quality, noise, stress, traffic congestion, inefficient urban infrastructure, anonymity, and social pathologies (Fattah et al. 2022; Nieuwenhuijsen 2021; Khomenko et al. 2022; Xi et al. 2022). To counteract the adverse effects of city life and ensure optimum housing quality for residents, adequate number of biodiverse green areas should be ensured.

According to Meerow (2020), planning reflects decision-making processes that determine which outcomes are prioritized, where green areas are sited, and how. Plants and green spaces are key components in planning sustainable cities The environmental contribution of plants is important for the development of sustainability in cities and in the future (Ong 2003). Providing appropriate areas for well-functioning green systems is basic way to shape the spatial structure of city (Douglas et al. 2017). Urban green areas are often located in spaces that are attractive for investment; therefore, these areas are vulnerable to functional transformation (Dymek et al. 2021). Therefore, it is important to determine which Development Plans are the most valuable part of the urban greenery system.

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Sustainable development is of fundamental importance in these plans, ensuring the city's functionality with intensive development, including the planning of communication routes and places of temporary rest. Some elements of urban infrastructure are located underground (car parks, road and rail tunnels, underground passages, networks, and utilities transmission), which also makes development difficult. This also applies to the arrangement and maintenance of green urban areas.

Lawns in cities are an inseparable part of urban greenery. A large number of green areas in cities worldwide consist of traditional intensively managed lawns which form 15–30% of urban green areas (Hedblom et al. 2017; Pereira and Baró 2022). Traditional green lawn offers different options for recreation and leisure, which also have aesthetic values (Ignatieva and Hedblom 2018; Zinowiec-Cieplik 2020). In addition to aesthetic experience, lawns have a range of ecosystem functions, such as action on the micro-climate of urban space, retention and infiltration of rainwater, and source of food for animals (Hall et al. 2016; Tang et al. 2018). According to Bolund and Hunhammar (1999), lawns provide six main groups of services in urban ecosystems: air filtration, micro-climate regulation, noise reduction, rainwater drainage, recreation, and cultural value. The capacity of city lawns for carbon and nitrogen storage is also interesting, and can be higher than the capacity of other grass stands outside the urban space (Pouyat et al. 2006; Raciti et al. 2008; Sieczka and Koda 2016).

Intensively managed lawns maintained by herbicides, fertilizers, irrigation, and frequent mowing have a high aesthetic value (Ignatieva et al. 2017; Yue et al. 2017; Yang et al. 2019;). However, this value comes at the cost of considerable water consumption, outflow of nutrients, and low species diversity (Robbins and Sharp 2003; Fissore et al. 2012;). The extensive management of lawns reduces the consumption of fertilizers and the necessity of mowing (Hugie and Watkins 2016). Lawns often include spontaneous plant species that serve as food sources for pollinators (Larson et al. 2014; Lerman and Milam 2016) and provides refuges and corridors within some limits for native flora and fauna (Wheeler et al. 2017; Hu et al. 2022).

The maintenance of traditional lawns is costly; therefore, solutions are required, that would reduce the costs without limitations in providing ecosystem services for lawns (Smith and Fellowes 2015; Tempesta 2015). In general, this problem can be resolved by reducing the maintenance of lawns and the number of cuts, which would contribute to more environment-friendly actions (Chollet et al. 2018; Bonthoux et al. 2019).

Extensive management of urban grasslands brings benefits such as lower maintenance costs and increased biodiversity. Nevertheless, extensively managed, and unmaintained urban grasslands are places with a high risk of fire. Dry and warm weather, combined with dry plant biomass, can lead to fires ((Winkler et al. 2021a).

Urban green spaces must be planned and located like other land use and built environment features, and this inevitably requires negotiating conflicting priorities (Meerow 2020). However, there seems to be a gap between theory and practice. For 20 years there has been a discussion about how the study area should be developed. So far, this area has been used as a lawn. Urban lawns, as ecosystems created by humans (Thompson and Kao-Kniffin 2017) have to cope with unfavorable pedological conditions such as compaction of lower soil profile layers or disturbed water regimes of soils, including limited capillarity. Coping with stressful conditions determinizes the survival of plant species in urban lawns. Therefore, lawn vegetation management has a essential influence. There is a hypothesis that different management of lawns changes competitive relations among species in this ecosystem on the background of very specific stress conditions in urban spaces. Three goals were set up to confirm or disprove the hypothesis to: (i) define the species composition of lawn vegetation, (ii) identify functional groups of plant species in urban lawns, and (iii) determine the impacts of different lawn management practices on species composition and ecosystem functions. The results of research on existing lawns can be used to choose the optimal method of managing and maintaining urban greenery, considering the conditions of spatial development and environmental factors. Urban lawns are often the only green infrastructure alternative, particularly in places with high concentrations of other engineering networks and traffic restrictions. By their very nature, lawns enable a quick solution to emergency situations, they do not represent a traffic obstacle, and yet they bring a number of benefits.

Materials and methods

Site characterization

The study was conducted in Warsaw (Poland) an area of which is 517.2 km^2. It has a population of approximately 1.7 million. Warsaw is situated in the Mazovian Lowland in central Poland. The city spreads on two main geomorphological formations: the Vistula River valley and the moraine hilly land, which are divided on the left riverside by the Warsaw Escarpment (Czarnecka et al. 2021). The city has a system of green areas that is well developed in the long run (Kuchcik et al. 2016), which comprises urban forests, parks, squares, roads protected areas and dwelling green areas. A quarter of the city area is covered with residential development, and the same area is covered with greenery (Kaczyńska 2020). Many urban green areas are situated along the Vistula River and its surrounding ares. Compared with other European cities, Warsaw is a city with riverine greenery and wood (Wilczyńska et al. 2021). However, in the center of Warsaw, the size of the green areas is very limited. The study locality in the center of Warsaw (area = 186.321 ha) is presented in Fig. 1.

The total green area in the selected area is approximately 14.8866 ha (including 2.8862 ha of lawns and 12.0004 ha of trees and lawns), which is approximately. 8% of the delimited center of Warsaw. The analyzed research lawns (L1; L2) are located above a tunnel that is part of the Warsaw Cross-City Line (Fig. 1), a 7 km railway underground line crossing the Central Warsaw in the east-west direction. A cross-city line is a key element of transport in Warsaw. The Warszawa Centralna Station is connected by underground passages to the Warszawa Śródmieście Station located entirely in an underground tunnel. The site is a typical urban space in which pedological conditions are strongly affected by building activities.

The development of the area where the studied lawns (L1; L2) are located has been extensively discussed by

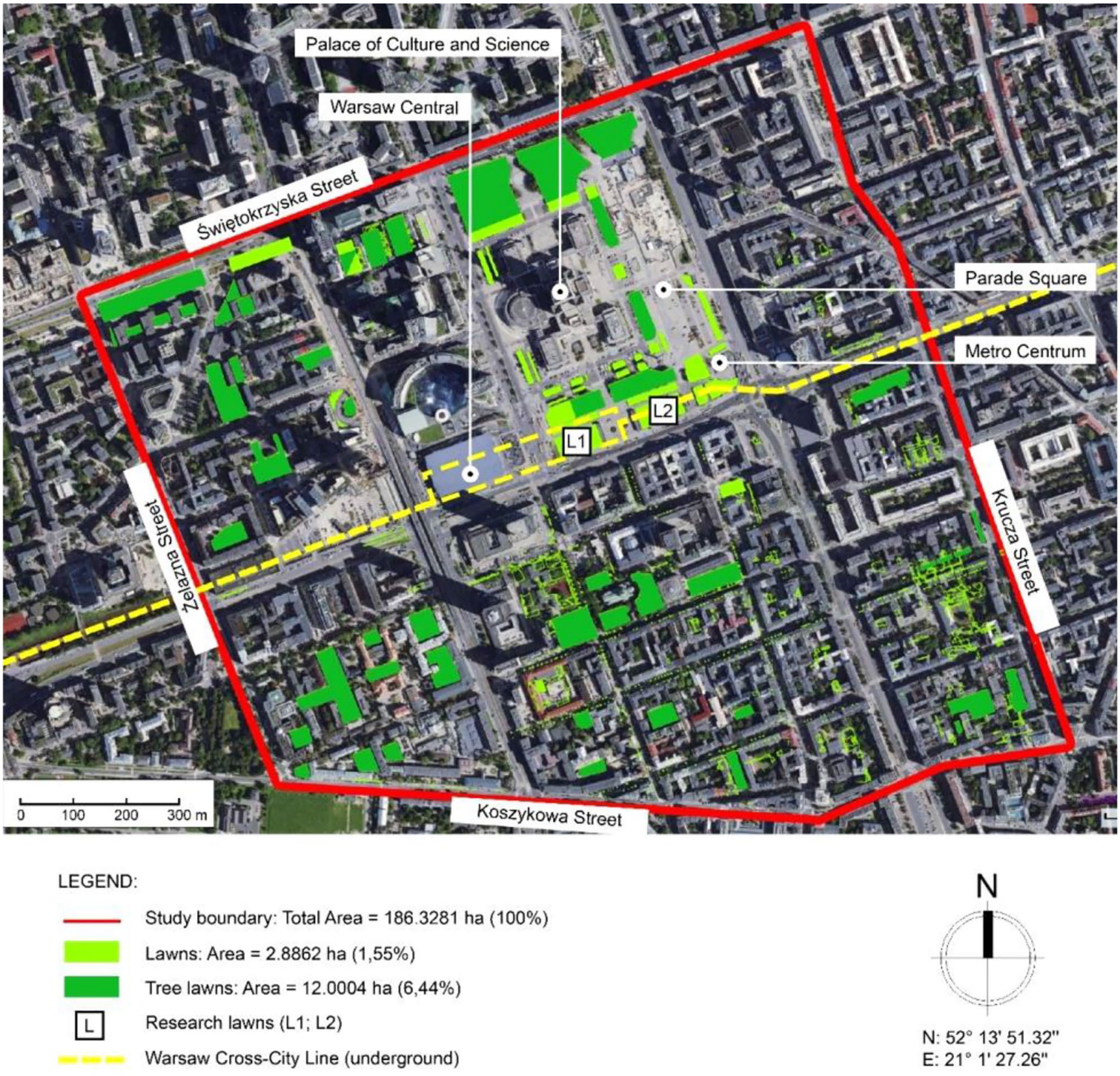

Fig. 1 The studied locality - current state on the orthophotomap (original study, based on https://polska.geoportal2.pl/map/www/mapa.php?mapa=polska, access: 8.08.2021)

local authorities, architects, and members of the community in Warsaw for over 20 years. The area is very attractive because of its communication location, an intense stream of people passing between the shopping center, Centrum metro station, and the above-mentioned railway stations, as well as active street trade and informal gatherings of people. An area lowered by the Centrum metro station is called Warsaw's Hyde Park, or "Patelnia" (ang. "The Pan"). Management of the Polish State Railways (PSR) was omitted in the discussions and plans for the development of the area, despite the fact that its main part is located above the railway tunnel, which condemned such plans to failure in advance. Permanent structures and water reservoirs cannot be established above the tunnel.

According to the current Master Plan, a significant part of lawns in this quarter will be removed because of planned investments (Resolution of the Warsaw City Authorities No. XCIV/2749/2010 of 9 November 2010), like the creation of a new City Centre, the construction of office buildings, commercial and cultural facilities. As a result, the lawn area will be reduced to 11.4732 ha, representing 6.16% of the demarcated center of Warsaw, (total area = 186.321 ha; lawns to be removed area = 3,4134 ha).

The examined lawns description

The monitored lawns (L1; L2) are located above the Warsaw Cross-City Line tunnel and are now part of the central public space (Fig. 2). The upper part of the study ground was made of soil-rubble fills. Pedological conditions can be characterized as anthropogenic with strongly altered and heterogeneous properties. The study site is an urban heat island, that is a place with a typical urban micro-climate. It is a locality with very specific stress conditions created by human civilization. In the immediate neighborhood, there are paved walkways for intensive pedestrian traffic between metro and railway stations.

Vegetation was assessed in lawns under two different management practices: (i) Traditional low lawn (TLL): The removal of biomass is performed 4–6 times during the growing season within traditional management. The number of cuts was determined based on the vegetation growth rate. The maximum height of the lawn is 0.4 m, then a cut follows. This is a common management practice applied to urban lawns over a long period (Fig. 3A). (ii) Tall city lawn (TCL): Here, management practice is applied with the goal of reducing costs related to urban lawns. The lawn was not

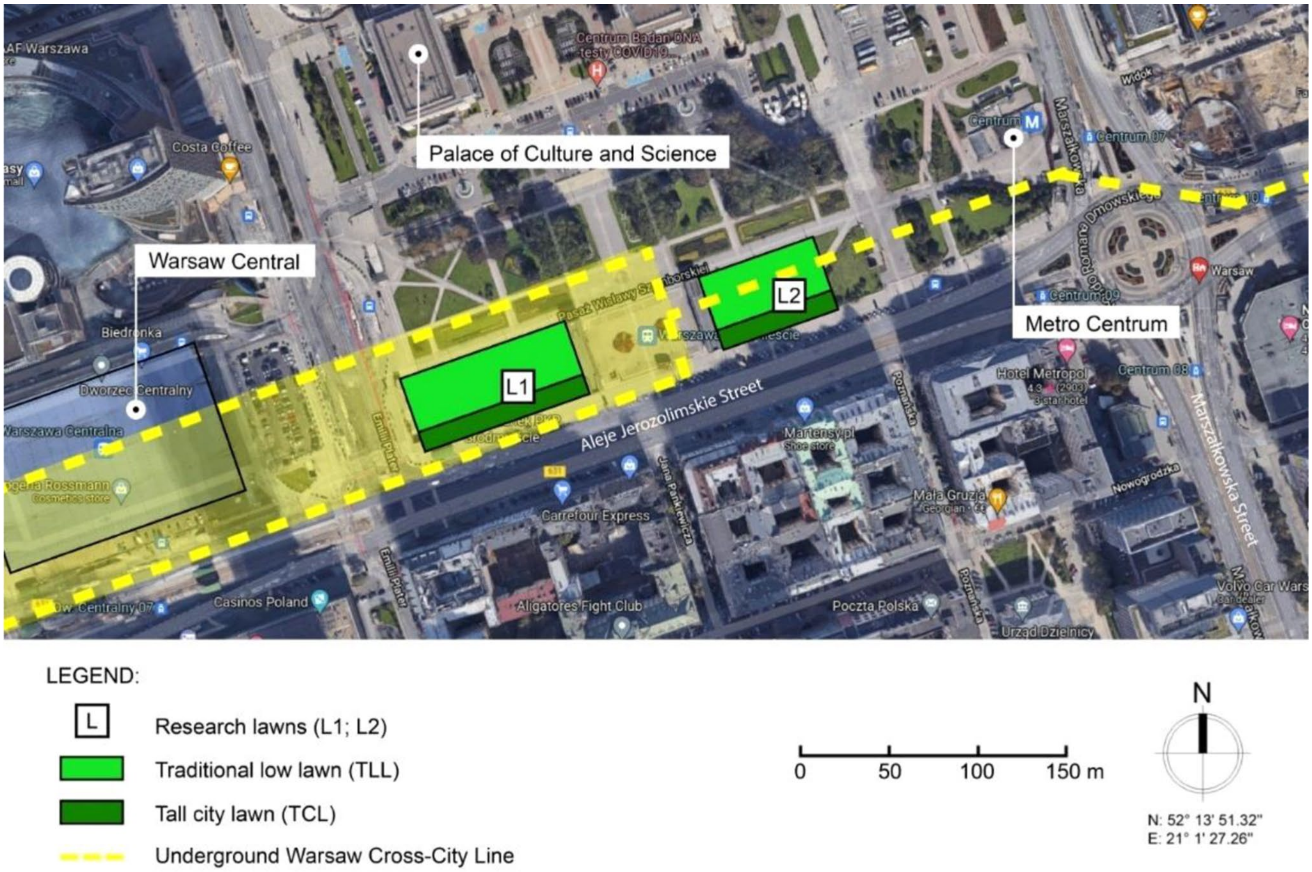

Fig. 2 The monitored lawns (traditional low lawn is marked in light green and high city lawn is marked in dark green), (original study, based on https://www.google.com/maps, access: 8.12.2021)

cut during the growing season or other cultivation measures (fertilization and, irrigation) were adopted. At the end of the growth, the biomass was mowed and removed (Fig. 3B).

Vegetation assessment

The vegetation was assessed using phytocoenological relevés sized 5 m^2. In each variant of the lawn, five plots were surveyed, on which vegetation assessment took place in July of years 2020 and 2021. First, all taxa of plants occurring in the phytocoenological relevé were identified, and then the degree of coverage was estimated for above-ground biomass of individual taxa. The scientific names of the plant species were obtained from the Pladias database of flora and vegetation (2021). The values of plant species coverage at the studied sites were subjected to a multidimensional analysis of ecological data. The choice of optimal analysis was ruled by the length of gradient identified by the Principal Component Analysis (PCA). The adjusted explained variation was calculated to be 48.6. Redundancy Analysis (RDA) was also used. Then, the data were processed using RDA to determine the correlation between plant species and lawn management. The RDA defines the spatial arrangement of individual plant species and variants of lawn management. Statistical significance was determined using the Monte Carlo test and 999 permutations were calculated. The data were processed using Canoco 5.0 computer program (Ter Braak and Šmilauer 2012).

Division of plant species into functional groups

Based on information from the Pladias database (2021), plant species were classified into several groups according to the selected characteristics: (i) Taxon origin: Taxa are divided into groups based on whether they are native or non-native in central Europe. The native taxon developed in the territory of Central Europe during evolution or appeared in Central Europe from the territory where it developed, without the contribution of humans. The non-native taxon has got to the territory of Central Europe from the territory in which it is native due to human activities, or by natural way from the territory in which it is non-native. Non-native taxa are classified as archeophytes and neophytes according to the time they were introduced in our territory. Archeophytes are non-native taxa introduced in the period between the beginning of Neolithic farming and year 1500, that is the time after the discovery of America, characterized by the development of overseas trade. Neophytes are non-native taxa that were introduced after 1500 years (detailed definitions see Richardson et al. 2000 and Pyšek et al. 2012). Non-native taxa that are cultivated more frequently in the Czech Republic (CR), but have not yet become wild, are presented separately. Data on the origin and time of introduction come from the Catalogue of non-native flora of the CR (Pyšek et al. 2012) where links are given to information sources about the origin of the taxa, which are complemented with some more recent findings. (ii) Plant height: Plant height is e related to the territory of Central Europe. They are presented in meters and applied to fully developed plants in a generative state growing in an open environment. Two values were mentioned for each taxon: minimum (common lower limit) and maximum (common upper limit). Data were obtained from the key to flora of the CR (Kaplan, 2019). (iii) Prevailing mode of pollen transfer: Pollen transfer onto the stigma is mediated by either abiotic vectors (carriers) such as wind (anemophilia) or biotic vectors such as insects (entomophilia). An alternative mechanism is self-pollination (autogamy), which can have various special forms, such as cleistogamy (self-pollination in incompletely developed, obligatorily autogamous flowers), pseudocleistogamy (self-pollination in flowers that are do not open due to unfavorable environmental conditions), or geitonogamy (self-pollination with pollen from the neighboring flower of the same plant when the pollen is not transferred by vector).

Fig. 3 The studied lawns in the center of Warsaw, year 2020: **A** - Traditional low lawn (TLL), **B** - Tall city lawn (TCL).

Information about the modes of pollination was obtained from the BiolFlor database (Durka 2002). (iv) Cultivation groups of plant species: Plant species were divided into three groups according to their properties and functions in the lawns. Group 1 includes grasses, which are representatives of the *Poaceae* family. This species forms the basis of lawn communities. Group 2 include legumes, which are representatives of the *Fabaceae* family. These plant species play important roles in nitrogen cycling. Group 3 represents other species, usually those that are undesirable in lawns and interfere with their function. (v) The share of life strategies: (Grime 1974, 1979) distinguished three basic ecological strategies of plants: competitive strategy (C), useful on stable sites with sufficient sources, not extreme conditions and limited interference; stress tolerant strategy (S), useful on sites with insufficient sources, extreme and very variable conditions but limited interference; and ruderal strategy (R), useful on sites with sufficient sources, not extreme conditions but with a frequently occurring interference. Taxa were allocated to life strategies using the method proposed by (Pierce et al. 2017). This method makes use of three key functional properties of leaves, which reflect differences in the investment of nutrients: leaf area (LA; is large in strongly competitive taxa), leaf dry matter content (LDMC; is high in taxa tolerant to stress) and specific leaf area (SLA; is large in ruderal taxa). These data were used to calculate scores that express the rate of C, S, or R selection on a percentage scale. The sum of the three scores for each taxon were 100%. Data on the properties of leaves for the calculations and/or directly calculated values were borrowed from the LEDA database (Kleyer et al. 2008) and other studies (Bjorkman et al. 2018; Dayrell et al. 2018; Findurová 2018; Tavşanoğlu and Pausas 2018). The Pladias database contains three scores for the C, S, and R strategies and the categorized life strategies. Values of the C-score, S-score, and R-score were examined for each taxon occurring in the phytocoenological relevé. The values were then used to calculate the mean values of the scores of life strategies for individual plant species in the relevé.

Results

A total of 72 plant taxa were identified during the survey, of which 39 were identified in TLL and 58 in TCL. The representation of the plant taxa on the monitored sites is presented in Appendix A. The results of the analysis were graphically expressed by means of ordination diagram (Fig. 4).

The results of the RDA which evaluated the coverage of plant taxa, were significant at a level of α = 0.001 for all canonical axes. Based on RDA analysis, the identified plant taxa were divided into four groups (Table 1).

The representation of the respective groups of species in lawns with different management methods is presented

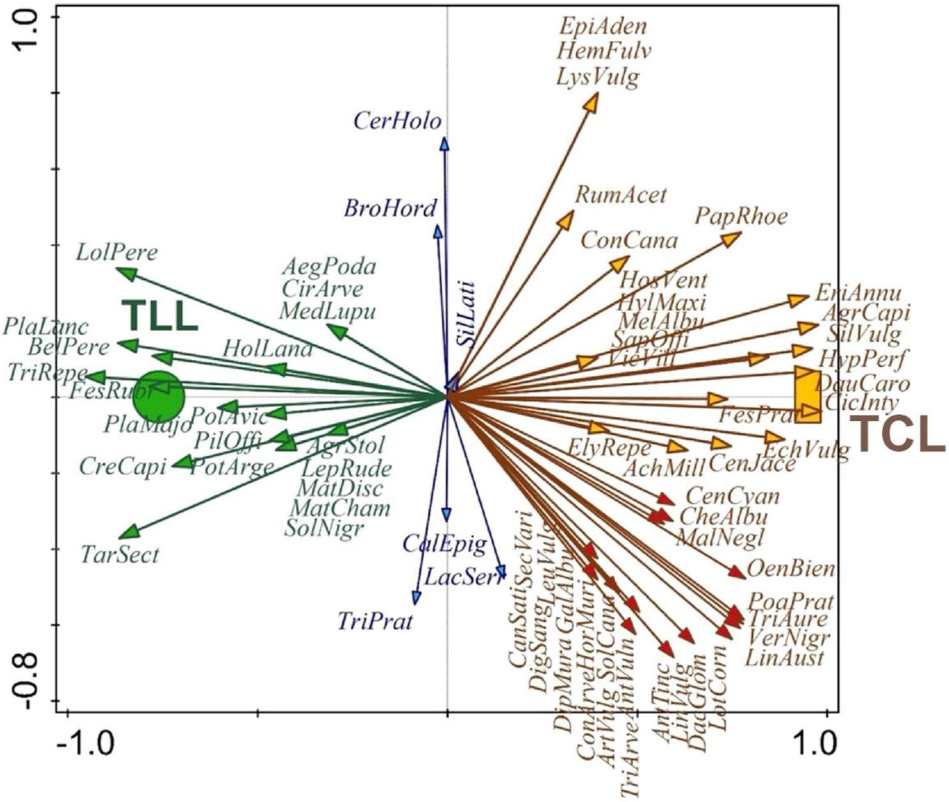

Fig. 4 Relation between the identified plant taxa and different lawn management methods (result of RDA; total explained variability = 48.6%; F ratio = 8.3.; P value = 0.001)

in Fig. 5. The species are divided into groups according to their origin, prevailing mode of pollen transfer and growing properties. The maximal height of plants was borrowed from the Pladias database (2021), and its average value was calculated. The average maximal height of species in TLL and TCL was 0.71 and 0.97 m, respectively. Figure 6 illustrates the shares of life strategies applied by the identified plant species.

Discussion

Urban green spaces play an essential role in the urban environment by providing a range of ecological, aesthetic, social, and economic benefits (Schrammeijer et al. 2022). Although cities are often considered "concrete jungles" (Hu et al. 2022), created natural enclaves, within urban areas can provide valuable ecosystem service. The role of lawns in the urban environment is multifaceted. From an ecological perspective, lawns provide several benefits. First, they can help reduce the urban heat island effect by reflecting solar radiation and cooling the air through evapotranspiration (Hu et al. 2021). Second, lawns can improve soil quality by promoting aeration and water infiltration, reducing soil erosion, and increasing organic matter content. Third, lawns can support biodiversity by providing habitat for a range of plant and animal species (Francoeur et al. 2021; Khare et al. 2021; Ervin et al. 2022).

Lawns play a significant role in different types of urban green spaces, such as parks, gardens, and public squares. lawns offer various recreational opportunities for urban residents, such as picnicking, sunbathing, and playing sports (Ignatieva et al. 2020). In parks, lawns are often used as a central gathering space for social activities and events such as concerts and festivals (Smith et al. 2021). They also provide an open space for physical activities such as jogging, yoga, and other fitness routines (Gaikwad and Shinde 2019). Lawns in parks can also contribute to the biodiversity of the area by providing habitats for insects and other small animals (Wenzel et al. 2020). In gardens, lawns are often used as a transitional space between the garden beds and borders. They can provide a neutral, green space that draws the eye and allows for easy movement through the garden. Lawns in gardens also offer a space for relaxation and contemplation, as well as a venue for social events, such as outdoor weddings and receptions (Hanson et al. 2021; Poniży et al. 2021). In public squares, lawns are often used to provide a calming oasis in the midst of the bustling city. They can offer a space for people to rest, relax, and enjoy the scenery. Lawns in public squares can also be used for small community events, such as outdoor concerts, art exhibits, and community meetings (Cao and Kang 2019; Carmona 2019; Deni et al. 2022).

Our results indicate that TCL featured 19 more species more than TLL and created phytocenosis richer in species. According to Bertoncini et al. (2017), lawns without the application of herbicides or other chemicals generally promote the occurrence of flowering plant species. Chollet et al. (2018) observed that a very low frequency of mowing has a beneficial effect on all aspects of species diversity, including functional and phylogenetic diversity. The reduced frequency of mowing offers an opportunity to convert of urban

Table 1 Groups of plant species classified based on the RDA analysis

Group	Species
Species of traditional low lawns (TLL)	*Aegopodium podagraria* (*AegPoda*), *Agrostis stolonifera* (*AgrStol*), *Bellis perennis* (*BelPere*), *Cirsium arvense* (*CirArve*), *Crepis capillaris* (*CreCapi*), *Festuca rubra* (*FesRubr*), *Holcus lanatus* (*HolLana*), *Lepidium ruderale* (*LepRude*), *Lolium perenne* (*LolPere*), *Matricaria discoidea* (*MatDisc*), *Matricaria chamomilla* (*MatCham*), *Medicago lupulina* (*MedLupu*), *Pilosella officinarum* (*PilOffi*), *Plantago lanceolata* (*PlaLanc*), *Plantago major* (*PlaMajo*), *Polygonum aviculare* (*PolAvic*), *Potentilla argentea* (*PotArge*), *Solanum nigrum* (*SolNigr*), *Taraxacum* sect. *Taraxacum* (*TarSect*), *Trifolium repens* (*TriRepe*).
Species of tall city lawns (TCL) – main group	*Agrostis capillaris* (*AgrCapi*), *Achillea millefolium* (*AchMill*), *Centaurea jacea* (*CenJace*), *Cichorium intybus* (*CicInty*), *Conyza canadensis* (*ConCana*), *Daucus carota* (*DauCaro*), *Echium vulgare* (*EchVulg*), *Elymus repens* (*ElyRepe*), *Epilobium adenocaulon* (*EpiAden*), *Erigeron annuus* (*EriAnnu*), *Festuca pratensis* (*FesPrat*), *Hemerocallis fulva* (*HemFulv*), *Hosta ventricosa* (*HosVent*), *Hylotelephium maximum* (*HylMaxi*), *Hypericum perforatum* (*HypPerf*), *Linaria vulgaris* (*LinVulg*), *Lysimachia vulgaris* (*LysVulg*), *Melilotus albus* (*MelAlbu*), *Papaver rhoeas* (*PapRhoe*), *Rumex acetosella* (*RumAcet*), *Saponaria officinalis* (*SapOffi*), *Silene vulgaris* (*SilVulg*), *Vicia villosa* (*VicVill*).
Species of tall city lawns (TCL) – subgroup	*Anthemis tinctoria* (*AntTinc*), *Anthyllis vulneraria* (*AntVuln*), *Artemisia vulgaris* (*ArtVulg*), *Cannabis sativa* (*CanSati*), *Centaurea cyanus* (*CenCyan*), *Convolvulus arvensis* (*ConArve*), *Dactylis glomerata* (*DacGlom*), *Digitaria sanguinalis* (*DigSang*), *Diplotaxis muralis* (*DipMura*), *Galium album* (*GalAlbu*), *Hordeum murinum* (*HorMuri*), *Chenopodium album* (*CheAlbu*), *Leucanthemum vulgare* (*LeuVulg*), *Linum austriacum* (*LinAust*), *Lotus corniculatus* (*LotCorn*), *Malva neglecta* (*MalNegl*), *Oenothera biennis* (*OenBien*), *Poa pratensis* (*PoaPrat*), *Securigera varia* (*SecVari*), *Solidago canadensis* (*SolCana*), *Trifolium arvense* (*TriArve*), *Trifolium aureum* (*TriAure*), *Verbascum nigrum* (*VerNigr*).
Species whose occurrence was affected by factors other than lawn management	*Bromus hordeaceus* (*BroHord*), *Calamagrostis epigejos* (*CalEpig*), *Cerastium holosteoides* (*CerHolo*), *Lactuca serriola* (*LacSerr*), *Silene latifolia* (*SilLati*), *Trifolium pratense* (*TriPrat*).

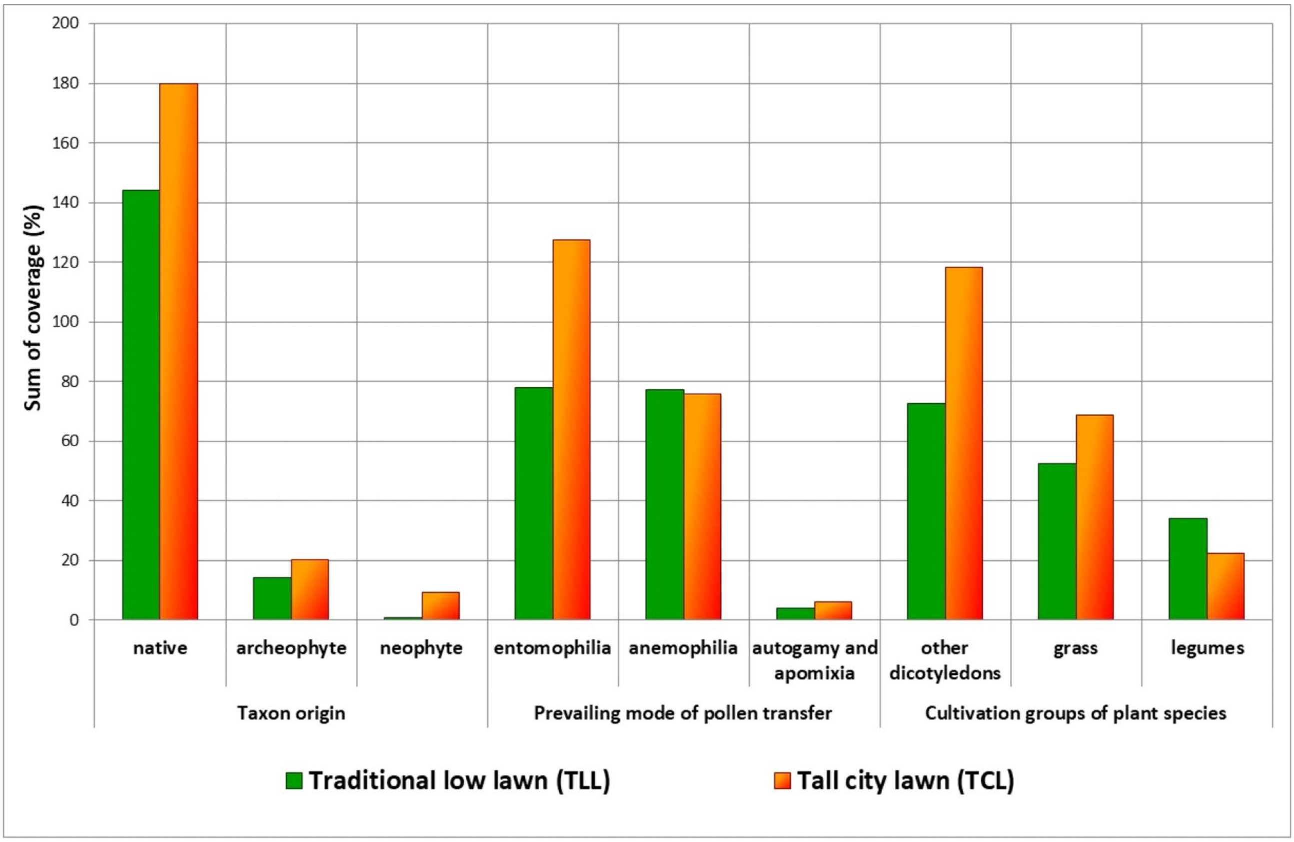

Fig. 5 Average degree of cover of the groups of species represented in the lawns

lawns into urban green fields/meadows. If we compare the number of species (39 plant species) in TLL, we can say that traditional low lawns are anthropogenic sites that are rather poor in species. The research findings were confirmed by Sikorska et al. (2020) who found that the number of species in the park lawns of Warsaw fluctuated from 16 to 25.

The results also showed that communities developing in lawns that are not cut differ in species. CCA analysis divided the species occurring in the TCL into two communities. Species of the subdominant position in the main group of species are *Agrostis capillaris, Daucus carota, Elymus repens, Achillea millefolium, Hypericum perforatum, Echium vulgare, Silene vulgaris* and *Festuca pratensis.* Species of the subdominant position in the subgroup were different and included *Poa pratensis, Linum austriacum, Trifolium aureum, T. arvense, Verbascum nigrum, Lotus corniculatus* and *Anthemis tinctoria.* Differences in species composition of vegetation are presumably a response to different soil conditions. Urban soils are increasingly being recognized as providers of ecosystem services (Delbecque et al. 2022). The soil profile in cities is often disturbed by construction work during which changes occur in the placement of individual soil layers or admixtures of building materials into the soil. These changes result in changes in the pedological environment in which the vegetation of urban lawns has to cope, which shows the distinctive heterogeneity of species composition.

Moreover, cities are centers of heavy metals (HM) emissions owing to intensive anthropogenic activities (Pan et al. 2018). Anthropogenic sources of HM in urban areas include industrial emissions, fertilizers, corrosion of construction materials, and coats (Kandic et al. 2019). After release, HM are transported by air and water streams, and finally deposited on soil surfaces owing to their high adsorbability on soil particles (Peng et al. 2022).

It has been confirmed that more frequent mowing is associated with a lower abundance and richness of bees in Tubingen, Germany (Wastian et al. 2016), lower butterfly diversity in Malmö, Sweden (Aguilera et al. 2019), and a decrease in native plant species in Xi’an, China (Zang et

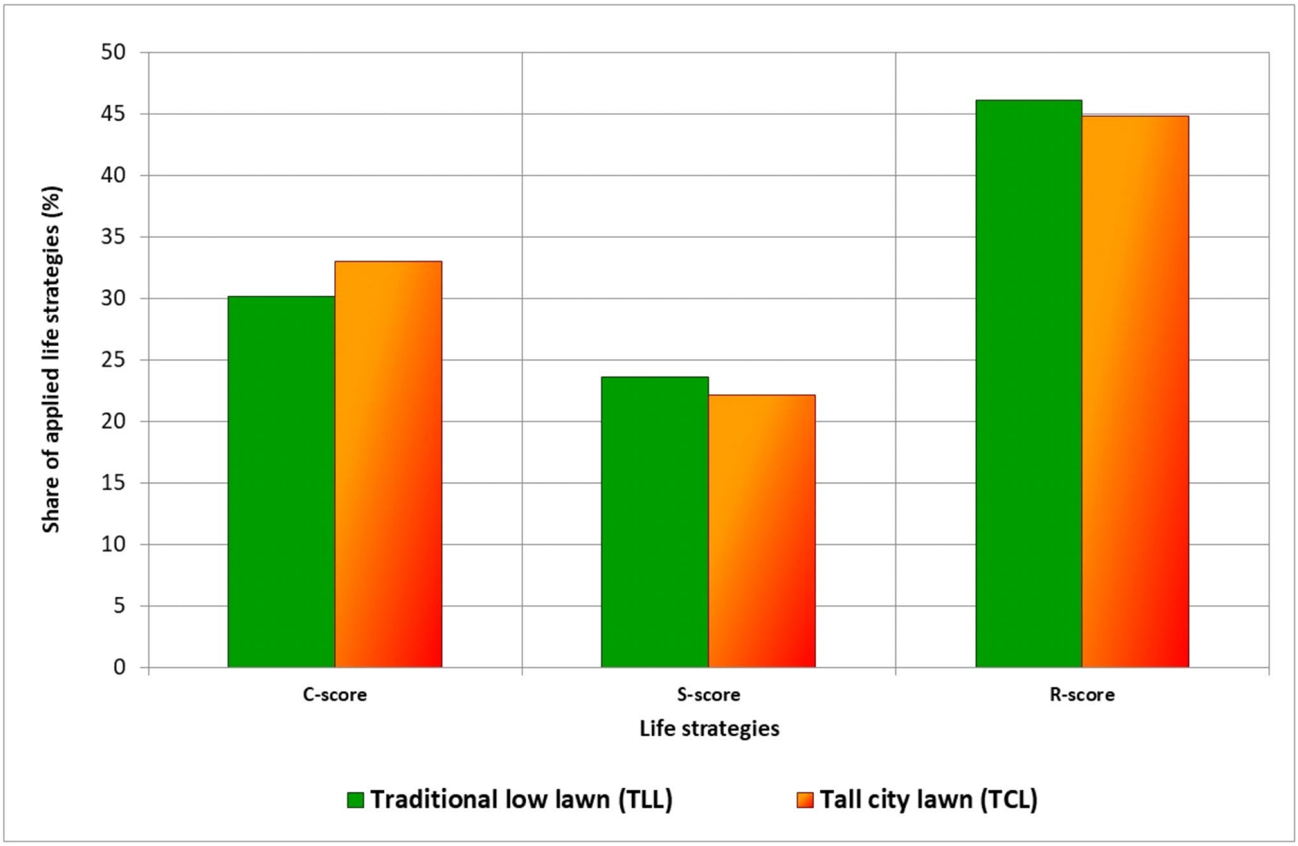

Fig. 6 Average share of the life strategies of species occurring in the lawn

al. 2019). Ecosystems with higher numbers of plant species provide insects and small vertebrates with multiple opportunities to get to food and maintain biodiversity in the urban environment. In general, lawns could serve as sources of food for fauna, including honeybees and butterflies living in urban environments (Öckinger et al. 2009; Matteson and Langellotto 2010; Zinowiec-Cieplik 2020). Globally, the occurrence of honeybees and other pollinators has recorded alarming reductions (Vanbergen et al. 2013; Baldock 2020). The small green areas in cities and towns could provide natural habitats for pollinators and mitigate the loss of diversity and its negative consequences (Goddard et al. 2010). Several scientific studies (Fischer et al. 2016; Harrison and Winfree 2015; Threlfall et al. 2015) indicate a surprising level of biodiversity and abundance of honeybees in towns. According to Baldock (2020), public greenspace areas, which are often managed by regular grass cutting, lead to the loss of most flowers. The potential impact of urban greenspaces was also investigated in four cities in the United Kingdom. the addition of flowers was found to increase the robustness of city-scale plant-pollinator communities (Baldock 2020).

The results indicated that both surveyed lawns were dominated by native plant species. The proportion of neophytes in the degree of coverage is lower than 10%. Similar results have been reported by Sikorska et al. (2020). According to their conclusions, the proportion of non-native species in Warsaw parks ranged from 2.7 to 8.7%. Therefore, it is obvious that urban lawns consist of phytocoenoses, with a low representation of neophytes. Different types of management promote the occurrence of native species. Despites this, attention should be given to the control of some neophytes such as *Conyza canadensis*, *Erigeron annuus*, *Oenothera biennis* and *Solidago canadensis*, particularly in TCL, where mowing is limited. Hu et al. (2022) pointed out that the origin of species is an important factor in judging the contributions to ecosystem services or biodiversity. According to Hufbauer (2018), an excessive proportion of neophytes and/or invasive species may weaken ecosystem stability. Adaptable invaders tend to establish vigorously in communities of native species and modify local ecosystems.

Studies have focused on the benefits of urban lawns; however, the fact that plants in lawns produce pollen may induce allergic reactions in sensitive persons. Studies on the allergenicity of urban green spaces are extremely important because a growing trend in the number of allergic sufferers has been observed (Jianan et al. 2007; Cariñanos et al. 2014; Kasprzyk et al. 2019). In this regard, anemophilic plant species are important, representing one of the adverse effects on human health in urban environment (Dudek et al. 2018; Kasprzyk et al. 2019; Vaverková et al. 2019; Cristofori et al. 2020). In TLL, flowering and pollen production can be reduced by cutting stands. Nevertheless, cutting in the growing season is not carried out in TCL; therefore, anemophilic plant species represent a source of pollen, and a source of allergic reactions. Entomophilic plant species can represent a potential 'disservices' too (Meerow 2020); many pollinators are dangerous for sensitive persons with allergic response to insect poison.

Grasses are important in the vegetation of lawns, primarily owing to their tillering capability and capacity to create a closed continuous canopy. A very crucial plant species is *Lolium perenne*. The closed green canopy performs both aesthetic and erosion control functions. Legumes capable of binding atmospheric nitrogen play an important role in the sustainability of lawn ecosystems. The representation of other dicotyledons is typically perceived as undesirable. However, this group also plays a role in the functioning of lawn ecosystems. The shape and structure of their root systems create non-capillary soil pores, which increase the infiltration capacity of the soil and retain water. The higher representation of dicotyledons in the TCL creates the potential for higher infiltration capacity in these areas. Bolund and Hunhammar (1999) claim that lawns inhibit the surface runoff and only 5 to 15% of rainwater run off the surface while the remaining rainwater penetrates deep into the soil or is evaporated. According to this definition, TLL represents a living space primarily for plant species of low height. Regular mowing reduces the occurrence of tall herb species. In contrast, TCL is an ideal living space for tall herbs that pushes out lower plant species owing to undisturbed growth. Lower grass species are less exposed to fire hazards in cities ((Winkler et al. 2021a).

The two studied types of lawns represent living spaces in which individual plant species apply similar life strategies. Figure 5 shows that lawns are suitable for species with prevailing ruderal life strategy. This strategy allows them to survive human disturbances, such as mowing, biomass removal, and the supply of nutrients, namely nitrogen. The plants also significantly apply their competitive strategy, which points to the stability of urban lawns. Under conditions, plants then compete for life factors. The lowest share is that of the stress strategy, which still exceeds a 20%. Thus, it is obvious that plant species in urban lawns are exposed to specific stress conditions which include the microclimate of urban spaces characterized by high temperatures and lack of water surplus. Salting of pavements and the action of waste or dog excrement can also be considered as stress factors. Thus, urban lawns are environments with relatively stable conditions, that are strongly influenced by human disturbance under specific stress conditions. These specific environmental conditions form a self-contained phytocenosis, which is represented by urban lawns. The specific conditions of urban lawns can be a space for the application of a new life strategy of plants (Winkler et al. 2023) and can also block and change the course of vegetation succession ((Winkler et al. 2021b).

Changes in the management of lawns point to a new and creative approach leading to the support of biological diversity in cities and reconsideration of the role played by lawns in the enrichment of urban areas. Less frequent mowing is a practical, economical, ecological, and time-saving alternative to the traditional lawns. This alternative has the potential to be widely accepted, provided that it can overcome obstacles to social acceptance (Lerman et al. 2018). Several studies suggest that management methods friendly to wild animals have a certain backing on the public. However, these lawns are more prone to the occurrence of weeds as well as to the occurrence of native plant species (Frankie et al. 2005), which may interfere with preferred goals such as aesthetics and easy maintenance (Lerman et al. 2012; Van Heezik et al. 2012).

Globalization and urbanization are the main drivers of urban landscape homogenization worldwide. Therefore, the flora and fauna of cities are markedly similar in different parts of the world despite geographical and climatic differences (McKinney 2006). The alternation of TLL and TCL has the potential to successfully resist this trend and increase the biological diversity of urban ecosystems.

City lawns in the study area did not hinder the use of railway tunnel and pedestrian communication routes on the surface. They are a space available for the organization of small gatherings of people and periodic cultural and commercial events. Lawns are easy to maintain and can be recreated in the event of the need to carry out renovation, modernization, and maintenance work on existing equipment and facilities.

Conclusion

Based on the findings, it can be concluded that the study area in the urban environment has unique conditions and functions that should be respected while also allowing for the creation of a biodiverse oasis that enhances aesthetic appeal and positively influences the microclimate. Urban lawns are a suitable type of vegetation that can be purposefully included in highly trafficked areas, and they represent a new and specific type of vegetation that co-creates an urban environment.

The results of vegetation analysis indicate that urban lawns are ecosystems with relatively stable conditions but are strongly influenced by human disturbance and the specific stress conditions of cities. Changes in the management of urban lawns can lead to changes in the species composition and affect the aesthetic perception of lawns. Tall city lawns can be an alternative approach to support biodiversity in the city and combat urban landscape homogenization. However, the heterogeneous composition of tall city lawns may lead to differing opinions among the city inhabitants.

The integrated planning of urban models that consider environmental and social trade-offs and synergies is essential for creating sustainable and diverse urban green areas. Findings of our study suggest that careful consideration and management of urban lawns can contribute to creating a more sustainable and biodiverse urban environment.

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